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MARTIAN SURFACE PHYSICAL PROPERTIES TO BE DERIVED BY RADAR ALTIMETER ON THE MARS OBSERVER SPACECRAFT

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Two of the primary objectives of the Mars Observer (MO) mission are global monitoring of those surface physical properties which can be linked with the recent climatic history of Mars, as well as characterization of planet-wide surface composition and mineralogy. While the main emphasis in orbital radar altimetry is quite naturally the determination of the topography of the planet, information concerning meter-scale roughness and the dielectric properties of the upper surface layer can be inferred from analysis of doppler and time-delay altimeter waveforms. In addition, it is relatively straightforward to use the time between altimeter pulse trains for passive microwave radiometry from which complementary data concerning surface emissivity (and hence dielectric properties) and roughness can be derived. The Pioneer Venus (PV) radar altimeter (17 cm wavelength), although in a highly elliptical orbit, was able to acquire valuable information concerning the roughness, radar reflectivity (r), and emissivity (e) of the venusian surface at coarse spatial resolution (30-100 km) for virtually all of the planet [1-3]. A 13.6 GHz (Ku-band or 2.2 cm wavelength) radar altimeter/radiometer (RAR), a candidate instrument for the Mars Observer [4], is capable of providing approximately 10 km resolution data on the surface roughness (C), microwave brightness temperature (Tb), emissivity (e), Fresnel reflectivity (r), and dielectric permittivity (k') for the entire martian surface. The complete waveform resulting from spreading of the altimeter pulses is saved (after being compressed) and used to derive the properties mentioned above by means of both a Hagfors scattering model (e.g. as used by Pettengill [1] and colleagues for PV, and to be used for Magellan altimetry), and an empirical scattering law (based upon the solution of an inverse scattering matrix problem as proposed by Tyler and Simpson for Magellan [5]).

As the MO is planned to be in a 360 km circular polar orbit, the derived altimeter surface properties can be obtained for the entire planetary surface at least three times (on the basis of the mapping orbit groundtracks), and thus seasonal effects can be directly assessed. This may shed new light on the proposition that seasonal variations in radar reflectivity (observed from Earth) in certain regions of Mars (e.g. Solis Lacus) are caused by the presence of liquid water on or near the surface [6,7]. Figure 1 is a theoretical volume mixing model approach for considering how much liquid water would be required to cause the observed seasonal variation in the radar reflectivity (i.e. a factor of 2) [8,9]. The model assumes that the water would occur as either grain coatings (as in clays) or as a pore fluid in the regolith or bedrock, and applies in general to radar reflectivity observations above 1 GHz [8,9]. As can be seen from the mixing curves (one for each type of surface, from very porous regolith to dense basalt [porosity less than 8 %]), between 8 to 10 vol. % liquid water would be required to cause the observed reflectivity variations. While regolith porosities of 8-10 % may be quite reasonable, saturation of the regolith by liquid water may not be

feasible on Mars except in regions where surface permafrost is dominant. For average porosity igneous and sedimentary rocks, between 1 and 5 vol. % liquid water would be required to account for the observed variations; thus, low vesicularity basalts with a few vol. % pore water could explain the increase. It should be noted however, that a few vol. % of a high permittivity phase such as ilmenite, rutile, pyrite, or even simple hematite could cause the observed reflectivity magnitudes [2,3,9]. For instance, 5-10 vol. % hematitic coating on average regolith grains (perhaps basaltic ash) would easily lead to reflectivities above 0.16 (the maximum observed), although a seasonal variation would not be expected. Perhaps the deposition and subsequent removal of porous eolian material (low permittivity) from a surface of lower porosity and greater enrichment in alteration products (e.g. hematite or pyrite) would serve as an alternate explanation to the seasonally varying reflectivity. Whatever the case, surface-layer permittivities derived from radar altimeter measurements on a seasonal basis should provide new insights on temporal electrical property variations (and porosity?), and perhaps on the activity of liquid water, especially if visual-IR mapping spectrometry can distinguish iron oxides from "wet regolith".

The surface properties derived from a Ku-band RAR in circular martian orbit are complementary and synergistic with other synoptic MO datasets such as thermal emission spectroscopy, Visual-IR mapping spectrometry, ultra high-resolution imaging (e.g. 1 m resolution), mm-wave radiometry, and HF-VHF sounding radar (to be flown on the PHOBOS mission in 1988 [10]). The depth penetration capabilities of 2.2 cm radar depend on the loss properties of the upper surface layer (and hence porosity and composition), but for Mars should vary from about 2 cm to 30 cm (for loss tangents between 0.1 and 0.001). More interesting is the possibility of detecting high permittivity regions which could be associated with near-surface concentrations of liquid water (as mentioned above and illustrated in Fig. 1), or to deposits of metallic-oxides or sulfides perhaps resulting from volcanism or weathering (or even to very high Ti basalts such as those discovered on the Moon). The multi-temporal seasonal coverage should permit some separation of mechanisms responsible for high permittivity surfaces to be established. The radiometer mode , as with PV, will help to refine estimates of the magnitude of high dielectric properties [2].

Surface physical/electrical properties derived from a RAR instrument on MO are a potentially important global and seasonal dataset which will complement measurements from other MO experiments (TEMS, VIMS, MOC etc.), and lead to a better understanding of the interaction of geological and climatological processes on the surface of Mars. This report merely illustrates some of the possibilities for answering fundamental questions with such measurements.

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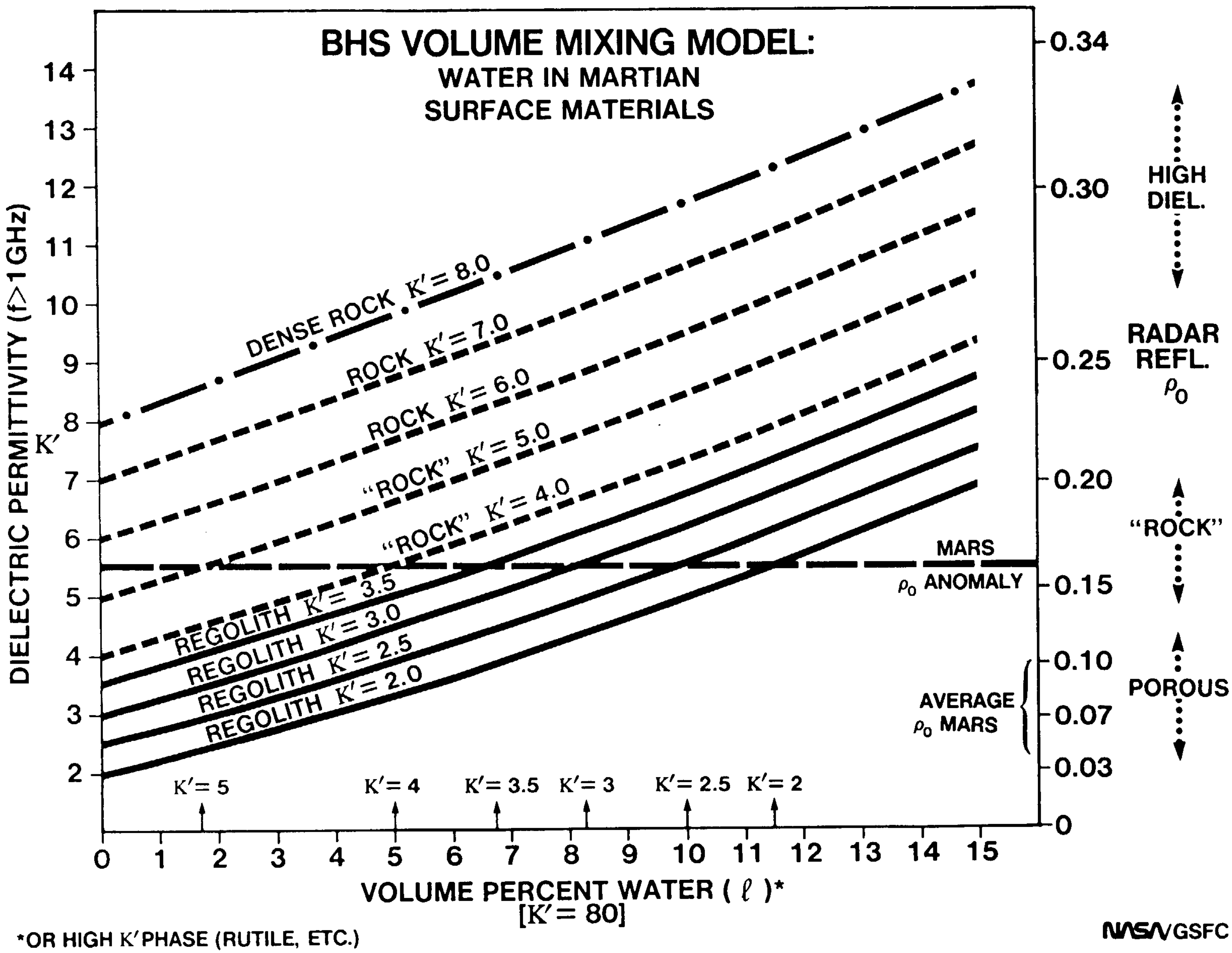

FIGURE 1: Theoretical volume mixing model curves [8,9]; see text for detailed explanation.